nature at high frequencies. The value of ε decreases from about 182 to 65 as the applied frequency increases from 800 Hz to 1 MHz. This may be attributed to the damping of dipolar polarization at higher frequencies [1,2]. Similar to dielectric constant, the loss tangent also shows almost frequency-independent properties at higher frequencies. However, $\tan\delta$ increases very sharply as we go towards the low frequency end. The rapid increase in $\tan\delta$ at low frequencies may be attributed to the contribution of dc conductivity to the loss tangent. Similar results have been observed by earlier works in ferroelectric films prepared on stainless-steel substrates [1]. The strong dependence of the dielectric properties of the samples may be attributed to in-homogeneity, presence of space layers at the sample-electrode interface, high porosity *etc.*

The ac conductivity of the samples were calculated using the relation

$$\sigma(\omega) = \omega\varepsilon_0\varepsilon''(\omega) = A\omega^s, \quad (1)$$

where $\varepsilon''(\omega)$ is the dielectric loss, ω is the angular frequency, ε_0 is free space permittivity, A and s are empirical parameters. Figure 2 shows the plot of $\log\sigma(\omega)$ *vs* $\log\omega$ at room temperature. As evident from Figure 2, the ac conductivity increases with increasing frequency and data can be fitted to $\sigma(\omega) = A\omega^s$, with a value of s very close to 0.3. A wide variance in the value of s for different systems have been reported by earlier workers [1-3]. The frequency dependent ac conductivity has also been observed in many semiconducting glasses and amorphous materials and is associated with electronic hopping conduction. The low value of the slope 's' in our sample can be explained in terms of hopping over the barrier (HOB) model as reported by other workers in semiconducting glasses [2].

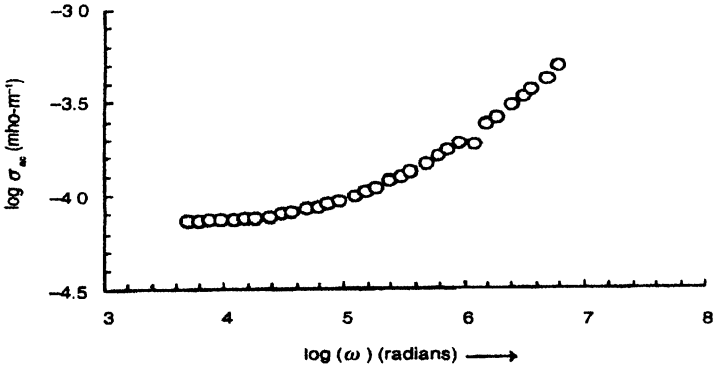

Figure 2. Variation of ac conductivity of lampblack sample with frequency.

Figure 3(a) and 3(b) respectively show the temperature-dependence of dielectric constant and loss tangent at three frequencies (10KHz, 100KHz and 1MHz). As evident from Figure 3(a), ε measured at 10KHz shows a broad peak at around 330K. The existence of dielectric anomaly peak shows that there is a possibility of a phase transition from polar to non-polar phase at 330K. The initial increase in dielectric constant of the samples may be attributed to the ordering of the dipoles in the samples and the reorientation along the applied ac field is maximum at the transition temperature. Further, increase in temperature beyond transition may lead to the disappearance of the dipoles (in the case of displacive type of materials) or random reorientation of the dipoles (in the case of order-disorder type of materials) so that the net polarization decreases. The sharpness and the magnitude of the dielectric anomaly peak decreases with increase in frequency. The anomaly peak is almost absent in ε measured at 1MHz frequency. Unlike the dielectric constant, loss tangent shows no anomaly peak in the measured temperature range. As evident from Figure 3(b), $\tan\delta$ increases with temperature. The absence of anomaly peak and continuous increase in $\tan\delta$ with temperature at 10KHz may be attributed to the rapid increase in dc conductivity in the samples at higher temperatures. This fact is supported by the rapid increase in $\tan\delta$ at low frequency (Figure 1). The rate of increase in $\tan\delta$ with temperature, decreases with increase in applied frequency. It shows almost temperature independent at 1 MHz. Similar behaviour has been observed in many materials where practically no dielectric anomaly is observed above certain frequencies due to damping of dipolar relaxation, even though a very sharp transition is indicated at low frequencies [1,4]. Similar behaviour has been observed in the dielectric properties of our samples.

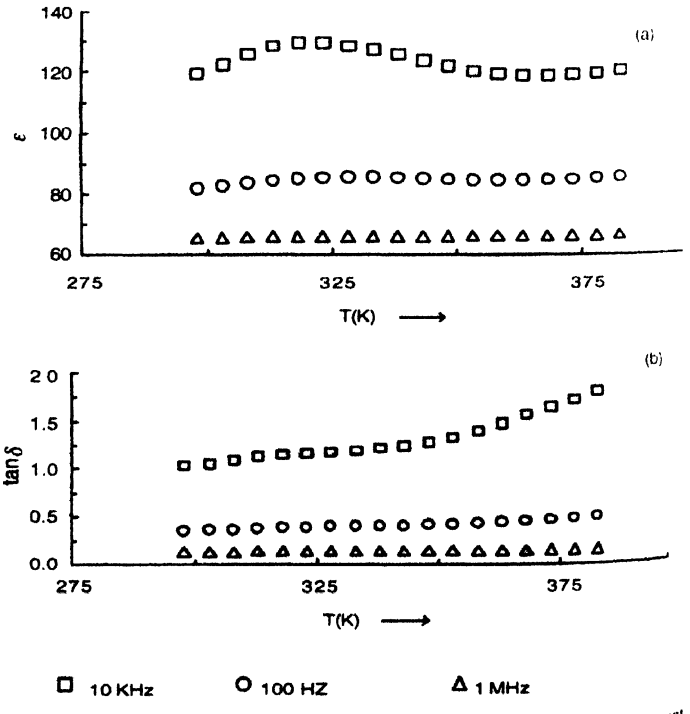

Figure 3. Variation of (a) dielectric constant (ε) and (b) loss tangent ($\tan\delta$) of lampblack sample at three frequencies.

The dc conductivity of the sample was measured as a function of temperature. Figure 4 shows a plot of dc conductivity ($\log \sigma_{dc}$) *vs.* $10^4/T$. As evident from Figure 4, there are two distinct regions, I (300K-330K) and II (330K-370K), with a discontinuity at 330K, thereby showing a phase transition at 330K. The activation energy was determined from Figure 4 using Arrhenius relation:

$$\sigma = \sigma_0 \exp\left(-E_a/kT\right), \tag{2}$$

where E_a is the activation energy, k is the Boltzman constant, σ_0 is the limiting dc conductivity, T is the temperature in Kelvin.

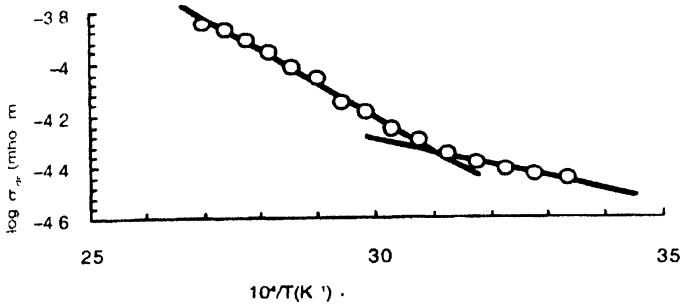

Figure 4. Temperature dependence of dc conductivity of lampblack sample

The values of E_a in the regions I and II are respectively, 0.13eV and 0.24eV. Similar results have been reported for fly-ash samples by other workers and have been attributed to ion-hopping type of conduction [5]. Similar models seem to be applicable to our samples also.

The electrical properties of lampblack samples have been studied. The samples showed a phase transition from polar to non-polar phase at about 330K. The dielectric studies show that the ac conduction in the samples can be explained by using hopping over the barrier model.

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